



## Smart Book Charts

*<These charts feed Smart Book and all charts are required. Please review questions on the next chart to ensure proper data control>*

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# TPSM: Heatshield for Extreme Entry Environment Technology (HEEET)



**STATUS QUO**

Venus in-situ science missions, high-speed sample return missions, Outer Planet probe missions and Human Missions beyond Lunar return speeds have no choice but to use a yet-to-be developed variant of heritage Carbon Phenolic, an unsustainable and missions limiting approach.



- 3-D Woven TPS has been shown to be viable
- Large design choices in tailororable WTPS provide us options to down select to a single weave/resin architecture that will have broad capability to fill the TPS gap
- Heat shield technology can be matured to TRL 5/6 by '16/'17 to enable SMD missions in the next round of NF/Discovery Proposal Cycle

## PROBLEM / NEED BEING ADDRESSED

TPS for extreme entry environment is solely dependent on the vanishing Carbon Phenolic and SMD in-situ science missions and higher speed human return missions are at risk

## PROJECT DESCRIPTION/APPROACH

- HEEET maturation has begun with architecture prioritized based on testing and analysis performed during the FY13 formulation activity
- The HEEET project will deliver a TRL 6 technology via:
  - Developing a mid-fidelity thermal response model
  - Will conduct thermal testing in the arc jet and laser testing at as high a heat flux as feasible to determine the range over which the material has robust and predictable response
  - A material property database will be developed and structural testing will be performed to validate thermal/structural models
  - Infrastructure to scale up weaving to NTE 3" thickness and at least 24" width will be put in place
  - A ~1m Engineering Test Unit will be fabricated and limited testing conducted which will validate workmanship and the structural modeling

**QUANTITATIVE IMPACT**

- Use of Carbon Phenolic results in entry g'loads of > 200 g's for Venus and OP missions
- Either or some combination of mass reduction by ~40%, compared to CP and g'load reduction by ~50% for extreme entry environment missions



**PROJECT GOAL**

- Mature the prioritized HEEET architecture to TRL 6 by FY17
- Work with the mission proposing organizations to successfully infuse HEEET into Discovery and New Frontiers proposals

**NEW INSIGHTS**



# HEEET Overview

HEEET is developing an efficient and innovative Thermal Protection System that can protect science payloads during entry where the heating is 2 orders of magnitude higher than for Space Shuttle or Mars missions. The ablative thermal protection system has already been recommended for use by SMD in Discovery AO and will enable missions to Saturn, Venus and the Outer Planets.

## Integration with Other Projects/Programs and Partnerships:

- CIF, SBIR/STTR Commercialization Readiness Program (CRP), SMD, STMD
- Discovery and New Frontier competed mission proposals
- ESA M4/M5 proposals
- Industry partnerships: Bally Ribbon Mills (BRM), Fiber Materials Inc. (FMI)

## Technology Infusion Plan:

- Mature WTPS architecture to TRL 6 by FY17 so that it can be adopted by proposal teams for the next round of NF and Discovery proposals – Near term target is Discovery 2014
- Potential Customers (PC) includes SMD, STMD, HEOMD and ESA

## Key Personnel:

**Program Element Manager:** Wade May

**Project Manager:** Ethiraj Venkatapathy

**HEEET Element Manager:** Don Ellerby

**Lead Center:** ARC

**Supporting Centers:** LaRC, JSC, KSC

**NASA NPR:** 7120.8

**Guided or Competed:** Guided

**Type of Technology:** Push and Pull

## Key Facts:

**GCD Theme:** Advanced Entry, Descent and Landing

**Execution Status:** Year 2 of 4

**Technology State Date:** 10/1/2013

**Technology End Date:** 9/30/2017

**Technology TRL Start:** 3

**Technology TRL End:** 6

**Technology Current TRL:** 3+

**Technology Lifecycle Phase:** Implementation



# TPSM: Conformal Ablative TPS (CA-TPS)



## STATUS QUO

- Limited number of certified TPS
- PICA tile on a rigid heatshields is limited by small size billet manufacturing and low strain-to-failure resulting in high tile count and gaps with filler design
- Honeycombed concepts (AVCOAT) require extensive touch-labor, large curing ovens, and complicated NDE



- Impregnate felt-based substrates with various polymers resulting in materials with high strain-to-failure that conform to conventional rigid aeroshells
- Concepts taken to TRL 2-3 under ARMD FAP Hypersonics (FY11) and ESMD EDL TDP showed survivability to stagnation heat fluxes approaching 500 W/cm<sup>2</sup>



## PROBLEM / NEED BEING ADDRESSED

NASA requires TPS ablator advances (TA14.3.1) to significantly lower the areal mass of TPS concepts, demonstrate extreme environment capability, demonstrate high reliability, demonstrate improved manufacturing consistency and lower cost

## PROJECT DESCRIPTION/APPROACH

- TPS Materials Development to TRL 5/6
  - Leverage NASA Ames TPS expertise, ETDD, and Fundamental Aero- Hypersonics investments
- Perform evaluation of felt substrates, impregnants, material processing and thermal/ablative property optimization
- Small scale tests to show aerothermal survivability at flight-like heat flux, pressure and shear including ground test instrumentation
- Measure thermal and structural properties
- Development of mid-fidelity thermal response models for design of mission TPS
- Partner with industry to manufacture materials (both felts and composites) at flight-like scale
- Deliver Conformal 1-m size Manufacturing Demonstration Unit (MDU)

**4-year development effort (FY12-15)**

## QUANTITATIVE IMPACT

Low cost, robust TPS solutions for mission applications:

- Mars 2018 class TPS
- COTS (eg. Dragon)
- ADEPT ViTAL rigid nosecap
- Backshell for Saturn, Venus and higher speed sample return
- High speed entry into Titan

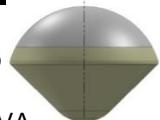


## PROJECT GOAL

- Deliver TRL 5/6 TPS material solution ready for mission implementation
  - Scale up demonstration
  - Tech transfer with industry partnership



1-m length  
Mid L/D  
MDU



Tech transfer to  
Small Probe  
Manufacturer TVA



# CA-TPS Overview

**CA-TPS is enabling small businesses and universities with low cost access to space by using off-the-shelf broad goods and transferring the processing technology for a light weight TPS. Use of CA-TPS materials will allow future missions to Mars, Venus and Outer Planets to save both mass and cost.**

## Integration with Other Projects/Programs and Partnerships:

- STMD, SMD – New Frontier proposals (TBD)
- Potential: IM LLC TRV, Orion
- Industry Partnerships: Applied Research Associates (ARA), Terminal Velocity Aerospace (TVA)

## Technology Infusion Plan:

- Establish mission development partnerships for conformal entry system architectures
- Work with Conformal TPS vendors on scale up approaches and develop tech-transfer approach
- Mission Infusion (MI) with TVA for small probe flight test
- Potential Customers (PC) includes SMD, STMD, HEOMD and commercial
- SMD interest in incentivizing CA-TPS use in next (FY16-17) Discovery proposals

## Key Personnel:

**Program Element Manager:** Wade May

**Project Manager:** Ethiraj Venkatapathy

**CA-TPS Element Lead:** Robin Beck

**Lead Center:** ARC

**Supporting Centers:** JPL, LaRC

**NASA NPR:** 7120.8

**Guided or Competed:** Guided

**Type of Technology:** Push

## Key Facts:

**GCD Theme:** Advanced Entry, Descent and Landing

**Execution Status:** Year 4 of 4

**Technology State Date:** 10/1/2011

**Technology End Date:** 9/30/2015

**Technology TRL Start:** 2

**Technology TRL End:** 5/6

**Technology Current TRL:** 4

**Technology Lifecycle Phase:** Implementation



# TPSM: 3D Woven Multifunctional Ablative TPS (3D MAT)



## STATUS QUO

- Orion EFT-1 compression pad design is complex and limited to LEO Return
- EFT-1 compression pad material was 2D laminate (similar to Apollo)
  - Apollo capsule was smaller; loads on compression pads were different
- EFT-1 design required metallic insert to mitigate failure in 2D material
  - Melting of metallic insert was predicted and observed
  - EFT-1 pad cracking was predicted & observed
  - Metallic insert design not suitable for beyond EFT-1 / LEO



- 3D Woven material can meet mechanical and thermal loads with minimal redesign
  - Leverage OCT funded WTPS development
  - Inter-layer tensile properties of 3D WTPS are much greater than 2D material
- 3D Woven will eliminate need for metallic insert, simplify the design, & reduce heating augmentation

## PROBLEM / NEED BEING ADDRESSED

Address current Orion MPCV Compression Pad design challenge – provide beyond LEO 3D woven compression pad material solution

## PROJECT DESCRIPTION/APPROACH

- **Phase I:** ~5 months and addresses key risk areas of WTPS for Compression Pad (Phase II approval depends on Phase I success)
  - Requirements for Lunar return
  - Resin Transfer Molding up to 3" thick woven preform
  - Alternative resins to enhance manufacturing options
  - Weave architecture – composition tailored to meet both mechanical & thermal loads
- **Phase II:** FY'13 through FY'15 development based on FY'12 efforts
  - Mature to TRL ~4
  - Build, test & demonstrate performance meets requirement
  - Deliver a prototype compression pad material along with documents and test reports
  - Technology transfer to MPCV prime contractor



## QUANTITATIVE IMPACT

- Early insertion of WTPS is feasible and highly advantageous for both GCD & MPCV
- With GCD investment early success = WTPS material being adopted by MPCV
- MPCV adoption of 3D MAT for the compression pad:
  - Results in near-term flight test data for a class of 3D Woven TPS
  - Compression Pad is both a structure and a TPS – the flight validated material will attract use by many programs including COTS, HEOMD and SMD



## PROJECT GOAL

- Deliver prototype 3D woven compression pad material at TRL ~4 by June of 2015 to meet summer 2015 CDR for MPCV EM-1 Lunar Return uncrewed flight test in FY'18



# 3D MAT Overview

3D MAT is developing a robust multi-functional material for use in spacecraft heatshields. The 3D-woven composite has pushed state of the art manufacturing to new levels yielding tailored materials that can be both structure and thermal protection system. The unique structural heat shield material is enabling future Orion missions to take humans far into the solar system.

## Integration with Other Projects/Programs and Partnerships:

- SBIR/STTR Commercialization Readiness Program (CRP), SMD, STMD
- Orion (mission infused for EM1)
- Potential: Under evaluation by Boeing (CST 100)
- Industry Partnerships: San Diego Composites (SDC), Bally Ribbon Mills (BRM)

## Technology Infusion Plan:

- Technology transfer to Lockheed Martin / Orion MPCV for further development and use as compression pads on EM-1 flight (2018) completed
- Jay Feldman is supporting Boeing's assessment of 3DMAT for potential use on their Commercial Crew vehicle (CST-100) compression pad
  - Boeing's CCtCap funding covers this work
- Potential Customers include STMD, SMD, HEOMD

## Key Personnel:

**Program Element Manager:** Wade May

**Project Manager:** Ethiraj Venkatapathy

**3D MAT Element Lead:** Jay Feldman

**Lead Center:** ARC

**Supporting Centers:** JSC, LaRC

**NASA NPR:** 7120.8

**Guided or Competed:** Guided

**Type of Technology:** Pull

## Key Facts:

**GCD Theme:** Advanced Entry, Descent and Landing

**Execution Status:** Year 3 of 3

**Technology State Date:** 7/1/2012

**Technology End Date:** 6/30/2015

**Technology TRL Start:** 2

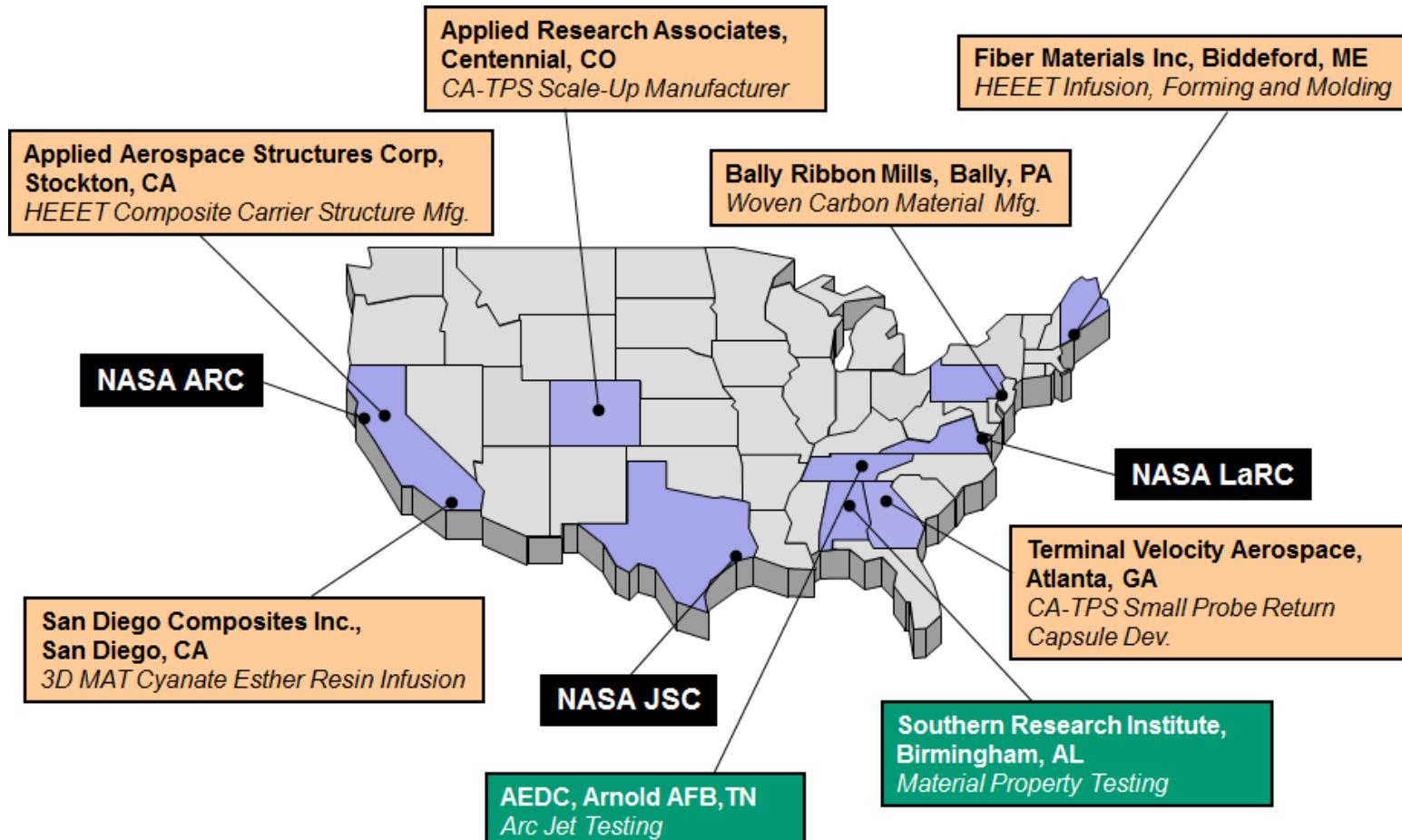
**Technology TRL End:** 4

**Technology Current TRL:** 4

**Technology Lifecycle Phase:** Implementation



# TPSM Project Organization and Key Members



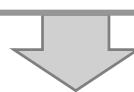
# Adaptable, Deployable, Entry and Placement Technology (ADEPT)



STATUS QUO

Robotic and human missions are limited by decades-old rigid, high ballistic coefficient aeroshells

- Geometry and packaging constraints within launch shroud or carrier spacecraft (secondary payload)
- Very high TPS certification and development costs and timeline
- Current EDL capability limits delivery of payloads to Mars surface at 1mT
- Probe missions to Venus experience 100s g's deceleration loads



NEW INSIGHTS

- Low ballistic coefficient aeroshell technology can reduce heat and g-loading during entry
- An innovative, mechanically deployable system:
  - Alternative approach to inflatable entry systems
  - Advances in 3-D carbon-cloth weaving provides a TPS that also sustains structural loads
  - Carbon cloth permits trade between ballistic coefficient and heating environment



## PROBLEM / NEED BEING ADDRESSED

Large payload ( $> 1\text{ Mt}$ ) delivery at Mars and next generation science missions require deployable, low ballistic coefficient entry systems not achievable with conventional aeroshell technology.

## PROGRAM DESCRIPTION:

- ADEPT develops a low ballistic coefficient aeroshell system that consists of a 3-D woven carbon cloth skin stretched over a mechanically deployable ribbed structure (similar to an umbrella)
- Design provides predictable structural loads via skin/ribs/struts behaving as a rigid system
- ADEPT entry conditions are well within the current arc jet capabilities – testable and certifiable
- Demonstration of aerodynamic stability and carbon fabric robust performance under entry loads
- Characterization of 3D woven carbon fabric for thermal & structural behavior
  - Carbon fabric testing under relevant heating conditions while under sustained bi-directional tension loads
- Design, integrate and test a 1m diameter class test article with flight-like carbon fabric design and structure attachment. Perform systems level testing in both ground and sounding rocket flight environments.

QUANTITATIVE IMPACT

PROGRAM GOAL

- ADEPT enables missions with breakthrough science capability and fills the 'gap' in future EDL needs
  - Enables 10x reduction in peak entry heating and deceleration loads
  - Venus in-situ atmosphere science now feasible for secondary payload missions
  - Mars robotic lander missions ( $>1\text{ mT}$ ) avoid supersonic chutes and can reach pole-pole landing sites without MOLA limits
  - Long term Mars Human Exploration to deliver 10s mT payloads are enabled with deployable low ballistic coefficient architecture



- Design, test, and demonstrate test article to TRL 6
- Fully mitigate all development challenges and risks to enable ADEPT as candidate technology for future Discovery class missions

Breakthrough capability to deliver entry system payloads to the most challenging mission destinations



# ADEPT Overview

## What would you say to a Senator that you meet in the elevator?

- The ADEPT project is a new, advanced heatshield design to protect payloads and landers delivered to planetary bodies with atmospheres. ADEPT is a mechanically deployable heatshield, like an umbrella, that can open up at planet arrival to diameters 2-5 times greater than current rigid heatshields. This large size overcomes the current limitations of NASA's heatshields to enable delivery of 10s of metric tons to Mars' surface – essential for human exploration.*
- Tweet: *"ADEPT is a mechanically deployable low-ballistic coefficient entry system (think: umbrella) which overcomes current limitations of rigid heatshields."*

## Integration with Other Projects/Programs and Partnerships

- CIF for Nano-ADEPT and wind tunnel testing
- UP Aerospace - Sounding Rocket (SR) flight test
- AVA avionics box baselined for SR
- SMD, STMD support
- Industry Partnerships: Bally Ribbon Mills (BRM), Thin Red Line Aerospace (TRLA)

## Technology Infusion Plan:

- Near term: PC, Low Ballistic Coefficient EDL (1 m class), SMD, Potential secondary payload or TDO for Discovery 2017
- Long term: PC, Low Ballistic Coefficient EDL (10+ m class), HEOMD, Potential use on large payload delivery (10s of MT) to surface of Mars.
- Targeting SMD Discovery 2017 AO and supporting EDL Pathfinder

## Key Personnel:

**Project Manager:** Paul Wercinski

**Lead Center:** Ames Research Center

**Supporting Centers:** LaRC, GSFC, AFRC, JPL

**NASA NPR:** 7120.8

**Guided or Competed:** Guided

**Type of Technology:** Push and Pull

## Key Facts:

**GCD Theme:** AEDL

**Execution Status:** Year 1 of 2 (1m scale development)

**Technology State Date:** Oct 1, 2014

**Technology End Date:** Sep 30, 2016

**Technology TRL Start:** 3

**Technology TRL End:** 5-6

**Technology Current TRL:** 3

**Technology Lifecycle Phase:** Implementation



# ADEPT Organization and Key Members

